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closing chapter, xxv, is devoted to a study of the relation of surface features to geologic structures.

Throughout the volume Mr. Geikie has limited himself to the more settled doctrines and principles of working geology, and has not attempted to present alternative views or possible objections. He has avoided the presentation of many of the problems now engaging the attention of structural geologists.

The photographic illustrations deserve special mention for their excellence, and among them the photographs of rock specimens are the most remarkable.

W. W. ATWOOD

The Viscous vs. the Granular Theory of Glacial Motion. By OSWIN W. WILLCOX. Long Branch, N. J.: Published by the author, 1906. Pp. 23.

This is less a treatment of the theme implied by the title than a review of a particular statement of one phase of the granular theory.[1] Even as a special criticism it goes wide of the mark, as the author, inadvertently it is to be assumed, substitutes easily demolished propositions of his own for those of the sponsors of the granular theory. As the leading feature of his discussion, Dr. Willcox attributes to the special sponsor he selects the unlimited proposition that "strictly crystalline minerals are incapable of manifesting viscous fluidity," whereas the real proposition is the very special one that "the retention of *its* crystalline structure," by the *ice granule*, during glacial *motion*, is incompatible with a *viscous flowage* of the granule. The "universal principle" thus substituted for the special proposition is attacked by the citation of the peculiar phenomena manifested by certain organic compounds, called, with more or less questionable propriety, "crystalline liquids" and "liquid crystals." These interesting phenomena have been all along known to some of the sponsors of the granular theory, presumably to all, and have awakened the question whether these "liquid crystals" are not short of being *typical liquids* to the extent that they are "crystalline," and short of being *typically "crystalline"* to the extent that they are liquids. The more vital question, however, is whether or not they *retain* their "crystalline" character while undergoing continuous and protracted motion under stress. Had these questions been sharply discussed, with full and critical data, the contribution would have been at least suggestive as to theoretical possibilities of behavior in ice granules, but it would not have touched the real question how they actually behave. Nothing truer can be said of this academic discussion of a universal proposition substituted for a concrete and special one, than is said by the author in another part of his paper, where the aspect of his discussion is reversed: "But the laws of nature, considered apart from their special modes of action, have little interest or value in either theory or practice."

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[1] Chamberlin, *A Contribution to the Theory of Glacial Motion*, University of Chicago Press, 1904.

By way of showing how concrete and special the real propositions involved in the granular theory are, they may be put as follows:

I. Glaciers are formed of individual crystalline granules. II. These are controlled by a strong crystalline force. III. They are, however, subject to growth and decadence, resulting in the extinction of some crystals and the enlargement of others, and in changes of relations to one another. IV. The crystals of any part seem to be the enlarged or reduced descendants of those in the part above. V. Collectively they persist throughout the whole glacial movement, and individually they seem to persist through some notable part of it, at least. VI. They participate in the changes of form and the changes of attitude involved in the glacial movement. Now:

1. If the granules are deformed by a viscous movement within themselves, they should show the fact by the recognized characteristics of viscous deformation and flowage.
2. If the granules are deformed by fracture and regelation, they should show the characteristics of this action.
3. If they are deformed by the sliding of the gliding plates of the crystals over one another, they should show this.
4. If they retain their crystalline integrity, save for additions and losses, they should show this.

These are very definite, concrete alternatives, to be settled by studies on the actual phenomena of glaciers, and in no other way. The incompatibility of the last with the first is the specific incompatibility urged, not the universal incompatibility of all kinds of crystallinity with all kinds of viscosity.

No evidence of the first is known to the reviewer; the second is manifested locally; the third seems to have an important place under special conditions of stress; while the fourth seems to be abundantly evidenced by the characters and attitudes of the granules. Dr. Willcox is a young chemist, with a geological penchant, whose lack of personal familiarity with the intimate structure of glaciers does not permit him to discuss these propositions on the only basis that is entitled to weigh—that of observation.

In the latter part of the paper he questions the adequacy of the energy available for glacial movement. Instead, however, of following carefully the postulates of the granular theory, he substitutes postulates of his own which any advocate of the theory would repudiate. For example, instead of trying to estimate the value of the gravitative pressure and the insolation, direct and indirect, which are the sources of the energy of movement assigned by the sponsors of the theory, he discusses the value of the *impact* of the moving granules, and seems seriously to regard the energy represented by the velocity of the granules as the total energy available!

Preliminary to an effort to show that there are narrow limits to the possibilities of glacial advance under the granular theory, the author says: "According to this theory, as it is stated by its sponsors, the elongation of a glacier is due primarily to the relief from compression afforded by the intergranular spaces;" and on this basis he proceeds to discuss the limits of the compression of the granules and the insufficiency of the intergranular spaces. His special sponsor for the theory, however, says, after detailed exposition: "These considerations lead to the view that movement takes place by the minute individual movements of the grains upon one another." It is difficult to find an excuse or palliation for such substitutions of propositions, indefensible on their face, for the propositions actually advanced by the sponsors of the granular theory. If a subject so infelicitous for academic treatment as the minute dynamics of glaciers is chosen at all, it is natural to expect it to be treated with academic fidelity.

T. C. C.